Tyvak
A Terran Orbital Corporation

Quick-Turn, Low Cost Spacecraft Development Principles

8-5-2016

2016 CubeSat Workshop
Logan, Utah

Tyvak Introduction

- We develop miniaturized custom spacecraft, launch solutions, and aerospace technologies for defense, intelligence, and scientific programs.
- We provide cost-effective solutions by utilizing agile aerospace processes and leveraging advanced commercial-off-the-shelf (COTS) electronic components.
- We design and manufacture sophisticated embedded software electronic devices such as avionics systems.
- Our team represents the leaders in aerospace miniaturization.
- We have supported 56 programs to date with 100% customer retention.

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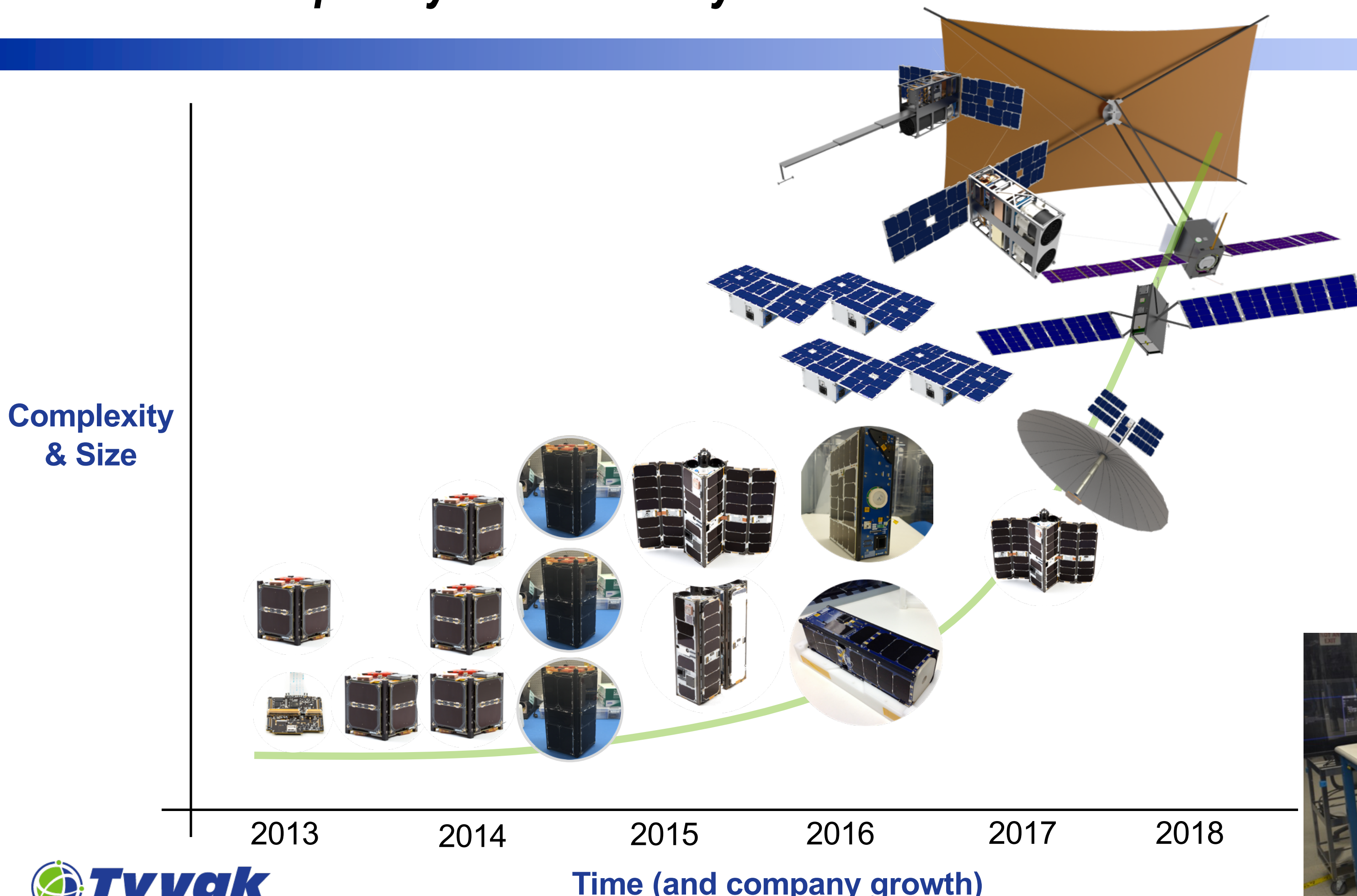
Tyvak: Satellite Solutions for Multiple Organizations

- Facts and Figures
  - Tyvak Nanosatellite Systems founded in 2011
  - Holding Terran Orbital Corp. founded in 2014
  - Tyvak International founded in 2015
    - *Fully independent European establishment*

- 3 locations, > 40 employees
  - Irvine, CA
  - San Luis Obispo, CA
  - Torino, Italy

Current Complexity Trends for Tyvak

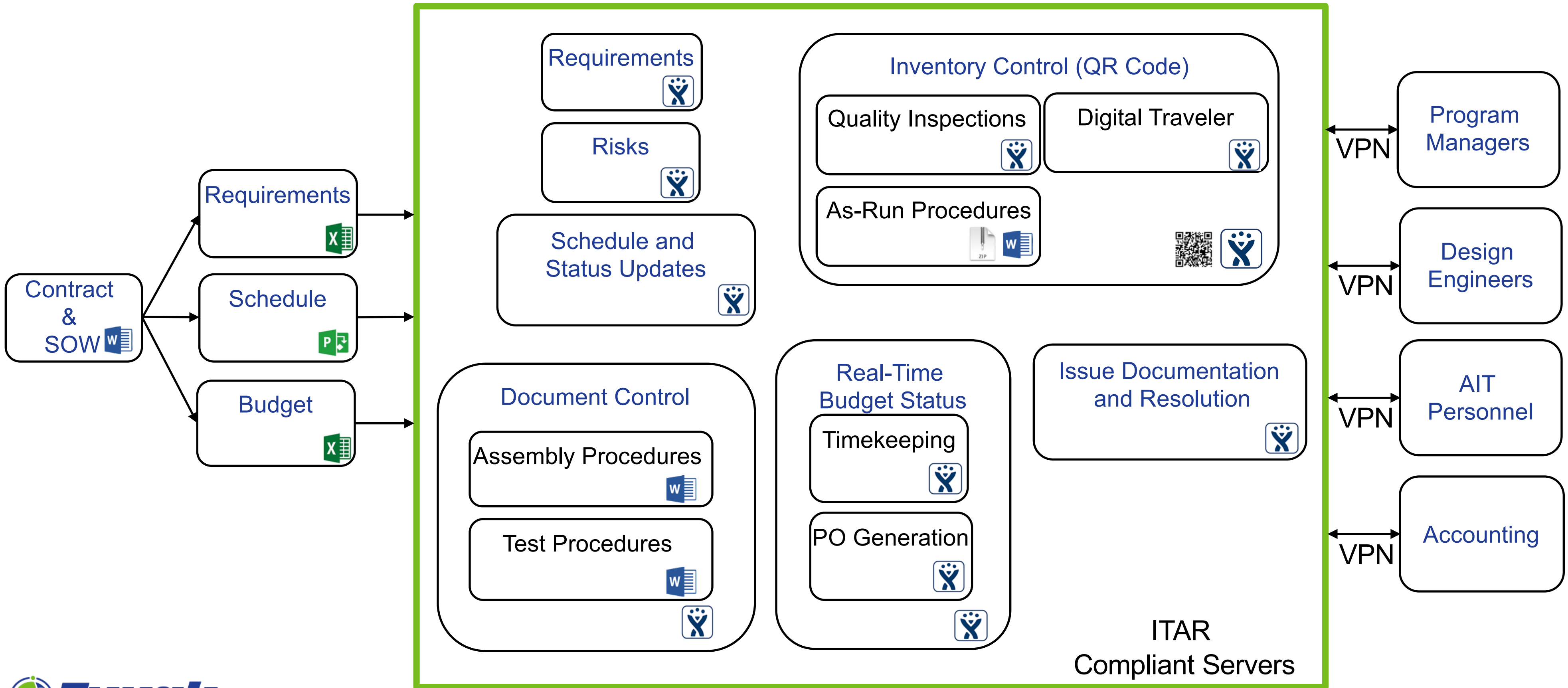


- Lots of applications
  - GPS Radio Occultation
  - Advanced Optics Demonstrations
  - Atmospheric Science
  - RF Signal Processing
  - Technology Demonstrations
- Challenges faced
  - Large variety of mission requirements
  - Delivering to a variety of customers
  - Satellites growing in complexity, size and numbers concurrent with company growth.
- Launching 15 satellites in 2016 and 2017

Addressing these challenges

- Company Structure, Processes, and Mission Assurance are key to addressing these challenges
- The design itself is usually fine, as it's the area that gets the most attention
- A tool is needed to comprehensively track the following during AIT:
  - Budget (materials and time-keeping)
  - Purchase Orders
  - Schedule
  - Requirements
  - Risks
  - Document Control and Approvals
  - Inventory
    - *As-Run Procedures*
    - *Supplier Non-Conformance*
    - *Digital Traveller*

Assembly Integration and Test Mission Assurance



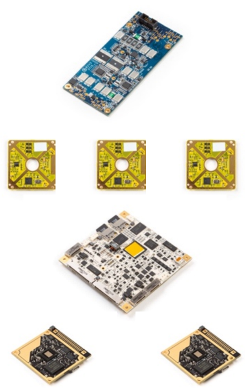
Satellite Testing Approach

- How do we maximize the effectiveness of hardware and software testing to achieve high levels of mission assurance at a lower cost?
- Three areas need to be considered:
  - Maximize test coverage throughout the AIT process.
  - To the greatest extent possible, test as you fly.
  - Ensure data produced during tests is accessible and easily analyzed for anomalies.

Test Coverage and Test Flow – Is the as-built unit functional as designed? Is functionality degraded at any point during qualification or acceptance testing?

TYVAK NANOSATELLITES

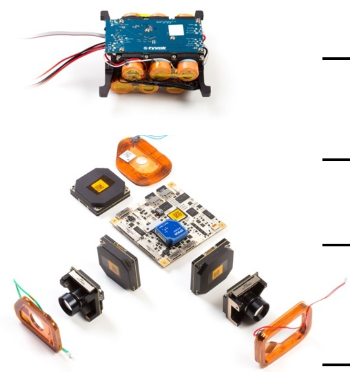
Components



Incoming Quality Control (Mechanical Parts, PCBs, Solar Cells, COTS Items)

1. Assign QR Code (digital traveler)
2. Visual Inspection
3. Assign to Inventory or Project
4. Record component specific info
5. Attach as-run test or modification procedures

Assemblies



Higher-Level Assemblies

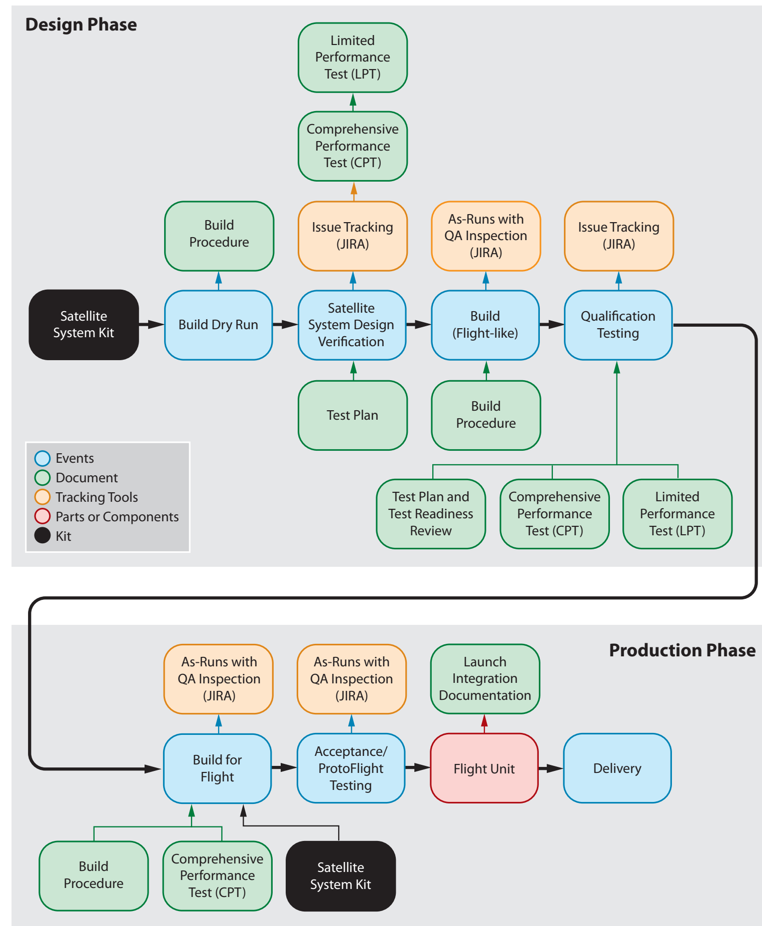
1. Assign QR Code (digital traveler)
2. As-run Assembly Procedures
3. As-run Test Procedures

Satellites

Final Vehicle Assemblies

1. Assign QR Code (digital traveler)
2. As-run Assembly Procedures
3. As-run Test Procedures

The final satellite build QR code includes a nested list of every assembly, and component contained within it, tracing a complete time-tagged history of hundreds of parts.



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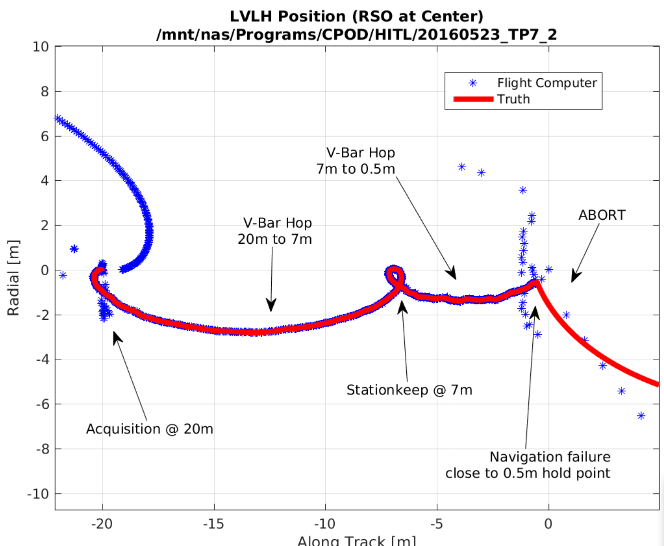
Test as you Fly – Hardware in the Loop (HITL) and Ground Software. Will the current system configuration (HW and SW) complete the mission?

- AIT vehicle level testing uses ground operations software during all functional checkouts
- Flight Software verifications through HITL simulations.
  - Below is an example of V-Bar hops from 20m, to 7m, to 0.5m with station-keeping between hops.
  - During the run, the navigation filter diverged, and the Fault Detection system issued (correctly) an abort command.
  - The same models can be deployed for Monte-Carlo analysis



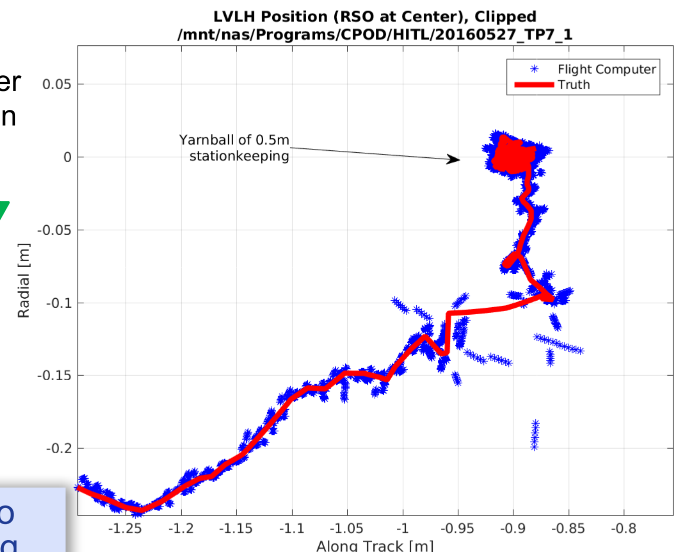
Issue with navigation filter gain settings was identified which caused an abort at 0.5m hold point

A config file parameter was changed over a UHF command from the ground station

Truth Models Include:

- Gravity, and Gravity Gradient
- Solar Pressure
- Atmospheric drag and torques
- Magnetic Field
- Earth Rotation, Nutation, and Precession

A combination of HITL, Monte-Carlo analysis, and Day in the Life Testing on Flight Units and Engineering Units are primary means of final software verification



The simulation was re-run and the system held at 0.5m for several hours

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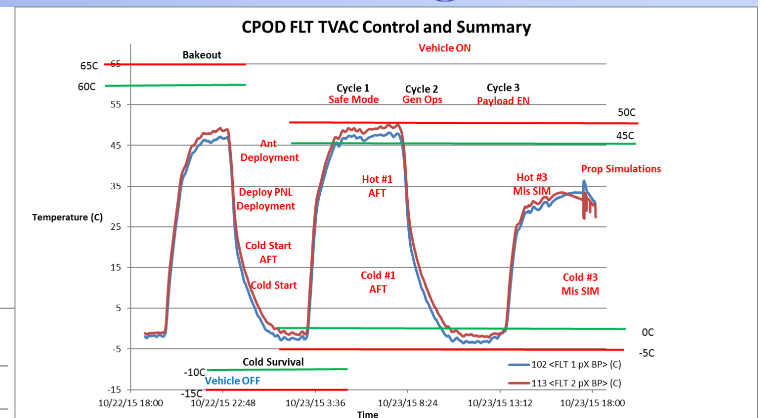
Data Review – Who reviews the data, and how?

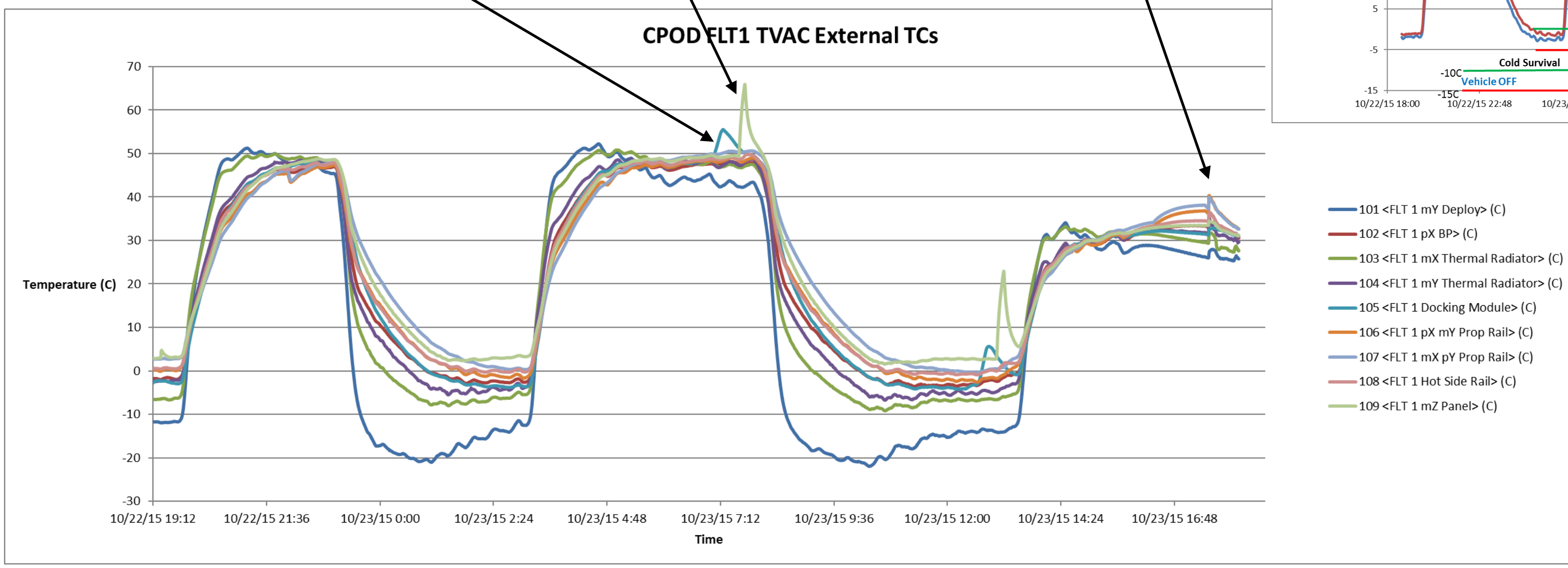
- During a 3 day TVAC test with two vehicles, each with >200 sensors, the data volume is massive.
  - Excel is not the tool for this level of analysis. Python is much better suited.
  - All sensors must have operational ranges defined
  - Smarts to pick out telemetry points operating outside acceptable range
  - Ability to easily query telemetry database for custom plots
  - Generate basic analytics on the data (max / min, averaging windows, etc)



Docking Magnet Turn On

S-Band File Downlink

Propulsion Sims



Closing Comments

- The mission assurance aspect of nanosatellites is ripe for innovation
- This innovation is iterative from program to program. Rapid program turn-over offers a short feedback loop.
- There is no agreed to standard for nanosatellite mission assurance currently. Different customers have different expectations. I believe the approach discussed gains the same benefits of traditional mission assurance (or maybe 97% of the way) with significantly reduced overhead.
  - The cost delta to achieve that final 3% is potentially enormous. It's the cost to address the perceived risk on the program. e.x. Is this particular lot code from this one manufacture suitable for flight, or is it a program risk that requires it be tracked, and discussed on a weekly call. The only actionable risk reduction is to redesign the board, or parts from the lot be radiation tested. Neither are practical.
- Our approach is to focus time, money, and effort on mission assurance aspects that offer measurable benefits, while producing tools to streamline team communication and documentation. The last 3% will be gained when large numbers of complex nanosatellite launch and operate. The perceived risk is then evaluated against flight historical data, and likely deemed unnecessary.
- The value proposition to this new approach for large constellations is readily apparent, and necessary. Enforcing the 3% is ironically (in my opinion), the number one risk for a large nanosatellite constellation program.